APPARATUS AND METHOD FOR ENCODING AND DECODING TFCI IN A MOBILE COMMUNICATION SYSTEM

PRIORITY

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This application claims priority to an application entitled "Apparatus and Method for Encoding and Decoding TFCI in a Mobile Communication System" filed in the Korean Industrial Property Office on June 12, 2000 and assigned Serial No. 2000-33107, the contents of which are hereby incorporated by
10 reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

15 The present invention relates generally to an apparatus and method for a TFCI (Transport Format Combination Indicator) code generator in a CDMA mobile communication system, and in particular, to an apparatus and method for encoding a TFCI in an NB-TDD (Narrowband-Time Division Duplex) mobile communication system.

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2. Description of the Related Art

In general, a CDMA mobile communication system (or an IMT-2000 system) transmits data frames of various services such as a voice service, an image service and a data service all together, using a single physical channel.
25 Such service frames are transmitted at either a fixed data rate or a variable data rate. As for the different services transmitted at a fixed data rate, it is not necessary to inform a receiver of a spreading rate of the respective service frames. However, regarding the services transmitted at a variable data rate, it is necessary to inform the receiver of a spreading rate of the respective service
30 frames. In the IMT-2000 system, the data rate is in inverse proportion to the data

spreading rate.

When the respective services use different frame transfer rates, a TFCI is used to indicate a combination of the currently transmitted services. The TFCI
5   secures correct reception of the respective services.

FIG. 1 illustrates an example in which an NB-TDD communication system uses the TFCI. Herein, the NB-TDD system employs 8PSK (8-ary Phase Shift Keying) modulation for high-speed transmission, and the TFCI bits are
10   encoded to a code of length 48 before transmission. As shown in FIG. 1, one frame is divided into two sub-frames of a sub-frame#1 and a sub-frame#2. Each sub-frame is comprised of 7 time slots TS#0-TS#6. Among the 7 time slots, the odd-numbered time slots TS#0, TS#2, TS#4 and TS#6 are used for an uplink transmitted from a mobile station to a base station, while the even-numbered time
15   slots TS#1, TS#3 and TS#5 are used for a downlink transmitted from a base station to a mobile station. Each time slot has a structure in which data symbols, a first part of TFCI, a midamble signal, SS symbols, TPC symbols, a second part of TFCI, data symbols and GP are sequentially time-multiplexed.

20   FIG. 2 illustrates a structure of a transmitter for transmitting a frame in a conventional NB-TDD communication system. Referring to FIG. 2, a TFCI encoder 200 encodes an input TFCI and outputs a TFCI symbols. A first multiplexer (MUX) 210 multiplexes the TFCI symbols output from the TFCI encoder 200 and other signals. Here, the "other signals" refer to the data symbol,
25   the SS symbol and the TCP symbol included in each slot of FIG. 1. That is, the first multiplexer 210 multiplexes the TFCI symbol and the other signals except for the midamble signal of FIG. 1. A channel spreader 220 channel-spreads the output of the first multiplexer 210 by multiplying it by a given orthogonal code. A scrambler 230 scrambles the output of the channel spreader 220 by multiplying
30   it by a scrambling code. A second multiplexer 240 multiplexes the output of the

scrambler 230 and the midamble signal as shown in FIG. 1. Here, the first multiplexer 210 and the second multiplexer 240 generate the frame structure of FIG. 1, under the control of a controller (not shown).

5   FIG. 3 illustrates a structure of a receiver in the conventional NB-TDD communication system. Referring to FIG. 3, a first demultiplexer 340 demultiplexes an input frame signal under the control of a controller (not shown), and outputs a midamble signal and other signals. Here, the "other signals" include the TFCI symbol, the data symbol, the SS symbol and the TCP symbol. 10 A descrambler 330 descrambles the other signals output from the demultiplexer 340 by multiplying them by a scrambling code. A channel despreader 320 channel-despreads the output of the descrambler 330 by multiplying it by an orthogonal code. A second demultiplexer 310 demultiplexes the signals output from the channel despreader 320 into the TFCI symbol and other signals, under 15 the control of the controller. Here, the "other signals" include the data symbol, the SS symbol, and the TCP symbol. A TFCI decoder 300 decodes the TFCI symbol output from the second demultiplexer 310 and outputs TFCI bits.

The TFCI is comprised of 1 to 2 bits to indicate 1 to 4 combinations of 20 the services, comprised of 3 to 5 bits to indicate 8 to 32 combinations of the services, or comprised of 6 to 10 bits to indicate 64 to 1024 combinations of the services. Since the TFCI is information indispensable when the receiver analyzes the respective service frames, a transmission error of the TFCI may prevent the receiver from correctly analyzing the respective service frames. Therefore, the 25 TFCI is encoded using an error correcting code so that even though a transmission error occurs on the TFCI, the receiver can correct the error.

FIG. 4 illustrates a scheme for encoding the TFCI using an error correcting code according to the prior art. Referring to FIG. 4, an extended Reed-30 Muller encoder 400 encodes an input 10-bit TFCI and outputs a 32-symbol TFCI

codeword. A repeater 410 outputs intact even-numbered symbols of the TFCI codeword output from the extended Reed-Muller encoder 400 and repeats odd-numbered symbols, thereby outputting a total of 48 coded symbols. In FIG. 4, a less-than-10-bit TFCI is constructed to have a 10-bit format by padding a value

5   of 0 from the MSB (Most Significant Bit), i.e., from the leftmost bit. The (32,10) extended Reed-Muller encoder 400 is disclosed in detail in Korean patent application No. 1999-27932, the contents of which are hereby incorporated by reference.

10   In the (32,10) extended Reed-Muller encoder 400, a minimum distance between codes is 12. After repetition, an input code is converted to a (48,10) code having a minimum distance of 16. In general, an error correction capability of binary linear codes is determined depending on the minimum distance between the binary linear codes. The minimum distance

15   (dmin) between the binary linear codes to become optimal codes is disclosed in a paper entitled "An Updated Table of Minimum-Distance Bounds for Binary Linear Codes" (A.E. Brouwer and Tom Verhoeff, IEEE Transactions on information Theory, VOL 39, NO. 2, MARCH 1993).

20   The paper discloses that the minimum distance required for the binary linear codes used to obtain a 48-bit output from a 10-bit input is 19 to 20. However, since the encoder 400 has a minimum distance of 16, the error correction encoding scheme of FIG. 4 does not have optimal codes, causing an increase in TFCI error probability in the same channel

25   environment. Because of the TFCI error, the receiver may misjudge a rate of the data frame and decode the data frame at the misjudged rate, thereby increasing a frame error rate (FER). Therefore, it is important to minimize a frame error rate of the error correction encoder for encoding the TFCI.

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SUMMARY OF THE INVENTION

It is, therefore, an object of the present invention to provide a (48,10) encoding and decoding apparatus and method for encoding a TFCI.

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It is another object of the present invention to provide an apparatus and method for encoding a TFCI in an NB-TDD CDMA mobile communication system.

10 It is further another object of the present invention to provide an apparatus and method for decoding a TFCI in an NB-TDD CDMA mobile communication system.

To achieve the above and other objects, there is provided an apparatus 15 for encoding k consecutive inputs indicating a TFCI of each of successively transmitted frames into a sequence of m symbols in an NB-TDD mobile communication system. An encoder encodes the k input bits into a sequence of at least 2^n symbols where $2^n > m$, using an extended Reed-Muller code from a Kasami sequence. A puncturer performs puncturing on the sequence of 2^n 20 symbols from the encoder so as to output a sequence of m symbols.

Preferably, the encoder comprises: a 1-bit generator for generating a sequence of same symbols; a base orthogonal sequence generator for generating a plurality of base orthogonal sequences; a base mask sequence generator for 25 generating a plurality of base mask sequences; and an operator for receiving the TFCI including a first information part indicating conversion to a biorthogonal sequence, a second information part indicating conversion to an orthogonal sequence and a third information part indicating conversion to a mask sequence. The operator is also for generating the sequence of 2^n symbols by combining an 30 orthogonal sequence selected from the base orthogonal sequences by the second

information part, a biorthogonal sequence constructed by a combination of the selected orthogonal sequence and the same symbols selected by the first information part, and a mask sequence selected by the third information part.

5   Preferably, the operator comprises a first multiplier for multiplying the same symbols by the first information part; a plurality of second multipliers for multiplying the base orthogonal sequences by TFCI bits constituting the second information part; a plurality of third multipliers for multiplying the base mask sequences by TFCI bits constituting the third information part; and an adder for
10 generating the sequence of 2^n symbols by adding outputs of the first to third multipliers.

      To achieve the above and other objects, there is provided an method for encoding 10 consecutive input bits indicating a TFCI of each of successively
15 transmitted frames into a sequence of 48 coded symbols in an NB-TDD mobile communication system, comprising: creating first sequences having a length 48 punctured orthogonal sequences; creating second sequences having a length 48 punctured mask sequences; multiplying the first sequences with each associated TFCI bit and the second sequences with each associated TFCI bit; and adding the
20 each resulting sequences calculated by the multiplication and outputting the sequence of 48 symbols wherein the punctured orthogonal sequences and the punctured mask sequences are sequences generated by puncturing following positions out of length 64 Walsh codes and length 64 masks; {0, 4, 8,13,16,20,27,31,34,38,41,44,50,54,57,61}

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BRIEF DESCRIPTION OF THE DRAWINGS

      The above and other objects, features and advantages of the present invention will become more apparent from the following detailed description
30 when taken in conjunction with the accompanying drawings in which:

FIG. 1 is a diagram illustrating a frame format used in a conventional NB-TDD CDMA communication system;

FIG. 2 is a diagram illustrating a structure of a transmitter for transmitting a frame in the conventional NB-TDD communication system;

5   FIG. 3 is a diagram illustrating a structure of a receiver for the conventional NB-TDD communication system;

FIG. 4 is a diagram illustrating a scheme for encoding a TFCI using an error correcting code according to the prior art;

FIG. 5 is a diagram illustrating a scheme for encoding a linear error 10 correcting code;

FIG. 6 is a flow chart illustrating a procedure for creating a mask function using a Kasami sequence family;

FIG. 7A is a diagram illustrating an apparatus for encoding a TFCI according to a first embodiment of the present invention;

15   FIG. 7B is a diagram illustrating an apparatus for encoding a TFCI according to a second embodiment of the present invention;

FIG. 8 is a flow chart illustrating an operation performed by the encoder of FIG. 7A;

FIG. 9 is a diagram illustrating an apparatus for decoding a TFCI 20 according to an embodiment of the present invention;

FIG. 10 is a flow chart illustrating an operation performed by the comparator shown in FIG. 9;

FIG. 11 is a diagram illustrating a structure of 1024 codes output from a (64,10) encoder according to an embodiment of the present invention; and

25   FIG. 12 is a flow chart illustrating an operation performed by the encoder of FIG. 7B.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

30   A preferred embodiment of the present invention will be described herein

below with reference to the accompanying drawings. In the following description, well-known functions or constructions are not described in detail since they would obscure the invention in unnecessary detail.

5   A CDMA mobile communication system according an embodiment of the present invention uses extended Reed-Muller codes to create optimal codes when encoding a TFCI. Commonly, a measure, i.e., a parameter indicating performance of a linear error correcting code, includes distribution of a Hamming distance of a codeword of an error correcting code. The Hamming distance refers

10   to the number of non-zero symbols in the respective codewords. That is, for a codeword '0111', the number of 1's included in this codeword, i.e., the Hamming distance is 3. The least value among the Hamming distance values of several codewords is called a "minimum distance (dmin)". The linear error correcting code has superior error correcting performance (or capability), as the minimum

15   distance is increased more and more.

The extended Reed-Muller code can be derived from a sequence determined by the sum (or XOR) of a specific sequence and an m-sequence. In order to use a sequence family (or group) including the sum of the sequences as

20   its elements, the sequence family must have a large minimum distance. Such specific sequence family includes a Kasami sequence family, a Gold sequence family and a Kerdock code family. Such specific sequences have a minimum distance of $(2^{2m}-2^m)/2$ for the full length $L=2^{2m}$, and a minimum distance of $2^{2m}-2^m$ for the full distance $L=2^{2m+1}$. That is, the minimum distance is 28 for the full

25   length 64.

Now, a description will be made regarding a method for creating an extended error correcting code which is a linear error correcting code having high performance, using the above stated sequence families.

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According to a coding theory, there exists a column permutation function for creating a Walsh code by cyclic-shifting the m-sequence. The m-sequence becomes a Walsh code when the sequences comprised of the specific sequence and the m-sequence are subjected to column permutation using the column

5 permutation function. The minimum distance by the sum (XOR) of the specific sequence and the Walsh code satisfies the optimal code property. Herein, a sequence obtained by column-permuting the specific sequence will be referred to as a "mask function (or mask sequence)." FIG. 5 illustrates a scheme for encoding the linear error correcting code. As illustrated, the present invention

10 provides a TFCI encoding scheme for making a complete coded symbol (or TFCI codeword) by adding a first coded symbol (or mask function) created by a first TFCI bit and a second coded symbol (or orthogonal code) created by a second TFCI bit.

15 Referring to FIG. 5, TFCI bits to be transmitted are divided into a first TFCI bit and a second TFCI bit and then, provided to a mask function generator 502 and a Walsh code generator 504, respectively. The mask function generator 504 outputs a given mask sequence by encoding the first TFCI bit, and the Walsh code generator 504 outputs a given orthogonal sequence by encoding the second

20 TFCI bit. An adder 510 then adds (XORs) the mask sequence from the mask function generator 502 and the orthogonal sequence from the orthogonal code generator 504, and outputs a complete TFCI codeword (or TFCI coded symbol). The mask function generator 502 may have mask sequences associated with every set of the first TFCI bits in the form of a coding table. The orthogonal code

25 generator 504 may also have orthogonal sequences associated with every set of the second TFCI bits in the form of a coding table.

Now, a description will be made of a method for creating the mask functions (or mask sequences) in the case where a $(2^n, n+k)$ code is created using

30 the Kasami sequence. Here, the "$(2^n, n+k)$ code" refers to a code for outputting a

TFCI codeword (or coded symbol) comprised of 2^n symbols by receiving (n+k) TFCI bits (input information bits). Actually, it is known that the Kasami sequence is represented by the sum of different m-sequences. Therefore, in order to create the $(2^n, n+k)$ code, a Kasami sequence of length 2^n-1 must be created

5 first. The Kasami sequence is equivalent to the sum of an m-sequence created by a generator polynomial f1(x) and a sequence obtained by repeating $2^{(n/2)}+1$ times a sequence of length $2^{(n/2)}-1$ determined by decimating the m-sequence in a unit of $2^{(n/2)}+1$. In addition, if the generator polynomial is determined, the respective m-sequences m(t), i.e., $m_1(t)$ and $m_2(t)$ can be calculated using a trace function in

10 accordance with Equation (1) below.

Equation (1)

$$m_1(t) = Tr(A\alpha^t), \quad t=0,1,..,30$$

$$\text{where, } Tr(\alpha) = \sum_{k=0}^{n-1} \alpha^{2^k}, \quad \alpha \in GF(2^n)$$

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In Equation (1), A indicates a value determined according to an initial value of the m-sequence, α indicates a root of the generator polynomial, and n indicates the degree of the generator polynomial.

20   FIG. 6 illustrates a procedure for creating the mask function in the case where the $(2^n, n+k)$ code (i.e., a code for outputting a 2^n-bit coded symbol by receiving (n+k) input information bits) is created using the Kasami sequence among the above-mentioned sequences. It is known that the Kasami sequence is represented by the sum of the different m-sequences. Therefore, in order to create

25 the $(2^n, n+k)$ code, a Kasami sequence of length 2^n-1 must be created first. The Kasami sequence, as described above, is created by the sum of an m-sequence created by a generator polynomial f1(x) and a sequence obtained by repeating $2^{(n/2)}+1$ times a sequence of length $2^{(n/2)}-1$ determined by decimating the m-sequence in a unit of $2^{(n/2)}+1$.

Referring to FIG. 6, in step 610, an m-sequence $m_1(t)$ created by the generator polynomial $f1(x)$ and a sequence $m_2(t)$ obtained by repeating $2^{(n/2)}+1$ times a sequence of length $2^{(n/2)}-1$ determined by decimating the m-sequence

5   $m_2(t)$ in a unit of $2^{(n/2)}+1$ are calculated in accordance with Equation (1). In step 620, a column permutation function $\sigma(t)$ for converting the m-sequence $m_1(t)$ into a Walsh code shown in Equation (2) below is calculated.

Equation (2)

10   $$\sigma : \{0,1,2,...,2^n-2\} \rightarrow \{1,2,...,2^n-1\}$$

$$\sigma(t) = \sum_{i=0}^{n-1} m_1(t)2^{n-1-i}$$

In step 630, 7 sequence families obtained by cyclic-shifting the m-sequence $m_2(t)$ 0 to 6 times are subjected to column permutation using $\sigma^{-1}(t)+2$,

15   where $\sigma^{-1}(t)$ is an inverse function of the column permutation function $\sigma(t)$ for converting the sequence $m_1(t)$ to the Walsh code. Further, '0' is added to the head of every sequence created by the column permutation so as to make the sequences have a length 2^n, thereby creating 2^n-1 sequence families $di(t)$ of length 2^n, where $i=0,..,2^n-1$ and $t=1,..,2^n$. The sequence families created in step

20   630 can be represented by Equation (3) below.

Equation (3)

$$\left\{ d_i(t) \middle| t = 1,...,2n, \ i = 0,...,2^{\frac{n}{2}} - 2 \right\}$$

$$d_i(t) = \left(\begin{array}{ll} 0, & \text{if } t = 1 \\ m_d(t + i - 2), & \text{if } t = 1,2,3,...,2^n \end{array} \right)$$

25

The calculated sequence families $di(t)$ are mask functions which can be

used as 7 masks.

One of the properties of the calculated sequence families di(t) is that a mask created by adding two different masks out of the above masks becomes

5 another mask out of the $2^{(n/2)}$-1 masks. To generalize further, all of the $2^{(n/2)}$-1 masks including a mask of all 0's can be represented by a predefined sum of n masks out of the $2^{(n/2)}$-1 masks. The n masks are defined as base sequences (or basis sequences).

10 The total number of codewords required in creating the $(2^n, n+k)$ code is 2^{n+k} which is the number of possible sets of the input information bits. Here, the number of biorthogonal sequences indicating 2^n orthogonal sequences (or Walsh sequences) and their complements is $2^n \times 2 = 2^n$-1, and the number of non-zero masks required to create the $(2^n, n+k)$ code is $(2^{n+k}/2^{n+1})$-1=2^{k-1}-1. In addition, all

15 of the 2^{k-1}-1 masks can also be represented by a predefined sum of the (k-1) masks on the basis of the property similar to that described above.

Next, a method for selecting the (k-1) masks will be described. In step 630, a sequence family is created by cyclic-shifting the $m_2(t)$ 0 to $2^{(n/2)-1}$ times.

20 An m-sequence created by cyclic-shifting the $m_2(t)$ i times can be expressed as $Tr(\alpha^i \cdot \alpha^t)$ using Equation (1). That is, a sequence family created by cyclic-shifting the $m_2(t)$ 0 to 6 times include the sequences created according to initial values $A=1, \alpha, .., \alpha^{2^n-2}$. At this moment, (k-1) linearly independent base elements are searched from the Galois elements $1, \alpha, .., \alpha^{2^n-2}$. The sequences corresponding to

25 the output sequences of the trace function taking the (k-1) base elements as initial values become base mask sequences. In this process, the linearly independent condition is represented by Equation (4) below.

Equation (4)

$\alpha_1,..,\alpha_{k-1}$: linearly independent

$\Leftrightarrow c_1\alpha_1 + c_2\alpha_2 + \cdots + c_{k-1}\alpha_{k-1} \neq 0, \quad \forall c_1,c_2,..,c_{k-1}$

5   A method for creating the generalized mask function will be described with reference to FIG. 6, for the case where a (64,10) code is created using the Kasami sequence family. Actually, it is well known that the Kasami sequence is represented by the sum of the different m-sequences. Therefore, in order to create the (64,10) code, a Kasami sequence of length 63 must be created first. The

10   Kasami sequence is comprised of an m-sequence created by a generator polynomial x^6+x+1 and a sequence created by repeating $2^{(n/2)}+1$ times a sequence of length $2^{(n/2)}-1$ determined by decimating the m-sequence in a unit of $2^{(n/2)}+1$. Here, if the generator polynomial is determined, each m-sequence m(t) can be calculated using the trace function as shown in Equation (5) below.

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Equation (5)

$m_1(t) = Tr(A\alpha^t), \quad t=0,1,..,63$

$$\text{where, } Tr(\alpha) = \sum_{n=0}^{4} \alpha^{2^n}, \quad \alpha \in GF(2^5)$$

20   In Equation (5), A indicates a value determined according to an initial value of the m-sequence and α indicates a root of the generator polynomial. In addition, n=6 because the generator polynomial is of the 6th degree.

FIG. 6 illustrates a procedure for creating the mask function in the case

25   where the (64,10) code (i.e., a code for outputting a 64-bit coded symbol by receiving 10 input information bits) is created using a Kasami sequence family among the above-stated sequence families. Referring to FIG. 6, in step 610, an m-sequence $m_1(t)$ created by the generator polynomial x^6+x+1 and a sequence

$m_2(t)$ obtained by repeating $2^{(n/2)}+1$ times a sequence of length $2^{(n/2)}-1$ determined by decimating the m-sequence $m_2(t)$ in a unit of $2^{(n/2)}+1$ are calculated in accordance with Equation (5). In step 620, a column permutation function $\sigma(t)$ for converting the m-sequence $m_1(t)$ into a Walsh code shown in Equation (6)

5 below is calculated.

Equation (6)

$$\sigma : \{0,1,2,...,63\} \rightarrow \{1,2,...,64\}$$

$$\sigma(t) = \sum_{i=0}^{4} m_1(t)2^{4-i}$$

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In step 630, 7 sequence families obtained by cyclic-shifting the m-sequence $m_2(t)$ 0 to 6 times are subjected to column permutation using $\sigma^{-1}(t)+2$, where $\sigma^{-1}(t)$ is an inverse function of the column permutation function $\sigma(t)$ for converting the sequence $m_1(t)$ to the Walsh code. Further, '0' is added to the head

15 of every sequence created by the column permutation so as to make the sequences have a length 64, thereby creating 7 sequence families $d_i(t)$ of length 64, where $i=0,..,6$ and $t=1,..,64$. The sequence families created in step 630 can be represented by Equation (7) below.

20   Equation (7)

$$\{d_i(t)|t=1,..,64, \ i=0,..,6\}$$

$$d_i(t) = \begin{pmatrix} 0, & \text{if } t = 1 \\ m_d(t+i-2), & \text{if } t = 1,2,3,..,64 \end{pmatrix}$$

The sequence families $d_i(t)$ calculated by Equation (7) are mask

25 functions which can be used as 7 mask sequences.

One of the properties of the calculated sequence families $d_i(t)$ is that a

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mask created by adding two different masks out of the above masks becomes another mask out of the 7 masks. To generalize further, all of the 7 masks can be represented by a predefined sum of 3 masks out of the 7 masks. As mentioned above, all of the mask sequences which can be represented by the predefined sum

5   of the masks, are defined as base sequences.

The total number of codewords required in creating the (64,10) code is $2^{10}=1024$, which is the number of possible sets of the input information bits. Here, the number of biorthogonal codewords of length 64 is 64×2=128, and the

10 number of masks required to create the (64,10) code is (1024/128)-1=7. In addition, all of the 7 masks can also be represented by a predefined sum of the 3 masks on the basis of the property similar to that described above. Therefore, a method for selecting the 3 masks is required. The method for selecting the 3 masks will be described below. In step 630, a sequence family is created by

15 cyclic-shifting the $m_2(t)$ 0 to 6 times. An m-sequence created by cyclic-shifting the $m_2(t)$ i times can be expressed as $Tr(\alpha^i \cdot \alpha^t)$ using Equation (5). That is, a sequence family created by cyclic-shifting the $m_2(t)$ 0 to 6 times include the sequences created according to initial values $A=1,\alpha,..,\alpha^6$. At this moment, 3 linearly independent base elements are searched from the Galois elements

20 $1,\alpha,..,\alpha^6$. It is possible to create all the 7 masks by the predefined sum of the 3 masks by selecting the sequences taking the 3 base elements as initial values. In this process, the linearly independent condition is represented by Equation (8) below.

25   Equation (8)

$\alpha,\beta,\gamma,\delta$: linearly independent

$\Leftrightarrow c_1\alpha + c_2\beta + c_3\gamma + c_4\delta \neq 0, \ \forall \ c_1,c_2,c_3,c_4$

Actually, 1, α and α^2 in the Galois field $GF(2^3)$ are basis polynomials

well known as the above 4 linear independent elements. Therefore, the following 3 mask functions M1, M2 and M4 are calculated by substituting the basis polynomials into Equation (5)

5   M1 = 0011010101101111101000110000011011110110010100111001111111000101
       M2 = 0100011111010001111011010101111011011110110001001011010000110111000
       M4 = 0001100011100111110101001101010010101111011011110101110001100011110

Now, a detailed description will be made regarding an apparatus and
10 method for encoding and decoding a TFCI in a NB-TDD CDMA mobile communication system according to an embodiment of the present invention. In the embodiments of the present invention, the encoder and the decoder use the base mask sequences calculated in the above method. Specifically, a method for creating the base mask sequences will be described below.
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First Embodiment

FIG. 7A illustrates an apparatus for encoding a TFCI in a NB-TDD CDMA mobile communication system according to a first embodiment of the present invention. Referring to FIG. 7A, 10 input information bits a0-a9 are
20 provided to their associated multipliers 740-749, respectively. A base Walsh code generator 710 generates base Walsh codes having a predetermined length. Here, the "base Walsh codes" refer to predetermined Walsh codes, by a predetermined sum of which all of desired Walsh codes can be created. For example, for a Walsh code of length 64, the base Walsh codes include a 1st Walsh code W1, a 2nd
25 Walsh code W2, a 4th Walsh code W4, an 8th Walsh code W8, a 16th Walsh code W16 and a 32nd Walsh code W32. A 1-bit generator 700 continuously generates a predetermined code bit. That is, as the invention is applied to the biorthogonal sequences, the 1-bit generator 700 generates a bit required for using orthogonal sequences as biorthogonal codes. For example, the 1-bit generator 700 constantly
30 generates a bit having a value '1', thereby to invert the Walsh codes generated

from the base Walsh code generator 710.

The Walsh code generator 710 simultaneously outputs Walsh codes W1, W2, W4, W8, W16 and W32 of length 64. The multiplier 740 multiplies the 1st

5 Walsh   code   W1 (=01010101010101010101010101010101010101010101010101010101010101 01) from the Walsh code generator 710 by the first input information bit a0. The multiplier 741 multiplies the 2nd Walsh code W2 (=0011001100110011001100110011001100110011001100110011001100110011)

10 from the Walsh code generator 710 by the second input information bit a1. The multiplier 742 multiplies the 4th Walsh code W4 (=0000111100001111000011110000111100001111000011110000111100001111) from the Walsh code generator 710 by the third input information bit a2. The multiplier 743 multiplies the 8th Walsh code W8 (=00000000

15 1111111100000000111111110000000011111111000000001111111) from the Walsh code generator 710 by the fourth input information bit a3. The multiplier 744   · multiplies the 16th Walsh code W16 (=0000000000000000111111111111111100000000000000001111111111111111) from the Walsh code generator 710 by the fifth input information bit a4. The

20 multiplier 745 multiplies the 32nd Walsh code W32 (=00000000000000000000000000000000111111111111111 11111111111111) from the Walsh code generator 710 by the sixth input information bit a5. That is, the multipliers 740-745 multiply the input base Walsh codes W1, W2, W4, W8, W16 and W32 by their associated input information bits a0-a5 in a symbol unit.

25 Meanwhile, the multiplier 746 multiplies the symbols of all 1's output from the 1-bit generator 700 by the seventh input information bit a6.

A mask generator 720 generates mask sequences having a predetermined length. The ·method for generating the mask sequences will not be described,

30 since it has already been described above. For example, when the (64,10) code is

generated using the Kasami sequence, the base mask sequences include a 1st mask sequence M1, a 2nd mask sequence M2 and a 4th mask sequence M4. The mask generator 720 simultaneously outputs the mask functions M1, M2 and M4 of length 64. The multiplier 747 multiplies the 1st mask function M1

5 (=0011010101101111101000110000011011110110010100111001111111000101) from the mask generator 720 by the eighth input information bit a7. The multiplier 748 multiplies the 2nd mask function M2 (=0100011111010001110110101111011011110110001001011010001101111000) from the mask generator 720 by the ninth input information bit a8. The multiplier

10 749 multiplies the 4th mask function M4 (0001100011100111110101001101010010101110110111101011100011001110) from the mask generator 720 by the tenth input information bit a9. The multipliers 747-749 multiply the input base mask sequences M1, M2 and M4 by the associated input information bits a7-a9 in a symbol unit.

15

An adder 760 adds (or XORs) the symbols output from the multipliers 740-749 in a symbol unit, and then, outputs 64 coded symbols. A symbol puncturer 770 punctures the 64 symbols output from the adder 760 according to a predetermined rule and outputs 48 symbols. That is, the (48,10) encoder

20 punctures 16 symbols from the 64 symbols created by the (64,10) code. The minimum distance of the (48,10) encoder varies depending on the positions of the 16 punctured symbols. Combinations of the 16 punctured positions, providing superior performance, are shown below. When using the following combinations of the punctured positions, the (48,10) encoder has the minimum

25 distance of 18 and provides superior weight distribution.

{0, 4, 8,13,16,20,27,31,34,38,41,44,50,54,57,61}

{0, 4, 8,13,16,21,25,28,32,37,43,44,49,52,56,62}

{0, 4, 8,13,16,21,25,31,32,37,43,44,49,52,56,61}

30 {0, 4, 8,13,18,21,25,30,35,36,40,46,50,53,57,62}

{0, 4, 8,13,18,21,25,30,35,37,40,47,50,53,57,62}

{0, 4, 8,13,19,22,27,30,33,36,41,44,49,55,58,61}

{0, 4, 8,13,19,22,27,30,33,36,41,44,50,52,56,63}

{0, 4, 8,13,19,22,27,30,33,36,41,44,50,52,58,61}

5   {0, 4, 8,13,16,20,27,31,34,38,41,44,50,54,57,61}

FIG. 8 illustrates a control flow for encoding a TFCI in an NB-TDD CDMA mobile communication system according to the first embodiment of the present invention. Referring to FIG. 8, in step 800, a sequence of 10 input

10 information bits a0-a9 is input and then, parameters code[] and j are initialized to '0'. The parameter code[] indicates the 64 coded symbols finally output from the encoder and the parameter j is used to count the 64 symbols constituting one codeword.

15   Thereafter, it is determined in step 810 whether the first information bit a0 is '1'. If the first information bit a0 is '1', the 1st Walsh code W1 (= 0101010101010101010101010101010101010101010101010101010101010101) is XORed with the coded symbol sequence parameter code[] of length 64. Otherwise, if the first information bit a0 is not '1', the control flow skips to step

20 812. After step 810, it is determined in step 812 whether the second information bit a1 is '1'. If the second information bit a1 is '1', the 2nd Walsh code W2 (=0011001100110011001100110011001100110011001100110011001100110011) is XORed with the coded symbol sequence parameter code[] of length 64. Otherwise, if the second information bit a1 is not '1', the control flow skips to

25 step 814. After step 812, it is determined in step 814 whether the third information bit a2 is '1'. If the third information bit a2 is '1', the 4th Walsh code W4(=0000111100001111000011110000111100001111000011110000111100001111 11) is XORed with the coded symbol sequence parameter code[] of length 64. Otherwise, if the third information bit a2 is not '1', the control flow skips to step

30 816. After step 814, it is determined in step 816 whether the fourth information

bit a3 is '1'. If the fourth information bit a3 is '1', the 8th Walsh code W8 (=0000000011111111000000001111111100000000111111110000000011111111) is XORed with the coded symbol sequence parameter code[] of length 64. Otherwise, if the fourth information bit a3 is not '1', the control flow skips to step 818. After step 816, it is determined in step 818 whether the fifth information bit a4 is '1'. If the fifth information bit a4 is '1', the 16th Walsh code W16(=0000000000000000111111111111111100000000000000001111111111111111) is XORed with the coded symbol sequence parameter code[] of length 64. Otherwise, if the fifth information bit a4 is not '1', the control flow skips to step 820. After step 818, it is determined in step 820 whether the sixth information bit a5 is '1'. If. the sixth information bit a5 is '1', the 32nd Walsh code W32(=0000000000000000000000000000000011111111111111111111111111111111) is XORed with the coded symbol sequence parameter code[] of length 64. Otherwise, if the sixth information bit a5 is not '1', the control flow jumps to step 822.

After step 820, it is determined in step 822 whether the seventh information bit a6 is '1'. If the seventh information bit a6 is '1', a sequence of all 1's is XORed with the coded symbol sequence parameter code [] of length 64. Otherwise, if the seventh information bit a6 is not '1', the control flow jumps to step 824. That is, in step 822, the Walsh code created in the preceding steps is XORed by 1 thereby to create a biorthogonal code. More specifically, if the seventh information bit a6 is '1', the parameter j is initialized to '0' and a jth parameter code[j] is XORed with '1'. Further, it is determined whether the parameter j is 63, in order to determine whether the parameter j is the last symbol of the codeword. If the parameter j is not 63, this process is repeated after increasing the parameter j by 1. In other words, in step 822, when the seventh information bit a6 is '1', a length-64 sequence of all 1's is XORed with a coded symbol sequence of length 64. Therefore, after repeating this process 64 times, the control flow proceeds to step 824 from the step for determining whether the

parameter j is 63.

After step 822, it is determined in step 824 whether the eighth information bit a7 is '1'. If the eighth information bit a7 is '1', the first mask

5 function M1 (= 0011010101101111101000110000011011110110010100111001111111000101) is XORed with the coded symbol sequence parameter code[] of length 64. Otherwise, if the eighth information bit a7 is not '1', the control flow skips to step 826. After step 824, it is determined in step 826 whether the ninth

10 information bit a8 is '1'. If the ninth information bit a8 is '1', the second mask function M2 (= 0100011111010001111011010101110110111101100010010110100011011100) is XORed with the coded symbol sequence parameter code[] of length 64. Otherwise, if the ninth information bit a8 is not '1', the control flow skips to step

15 828. After step 826, it is determined in step 828 whether the tenth information bit a9 is '1'. If the tenth information bit a9 is '1', the fourth mask function M4 (= 00011000111001111101010011010100101111011011101001011110110   1111010111000110001110) is XORed with the coded symbol sequence parameter code[] of length 64. Otherwise, if the tenth information bit a9 is not '1', the control flow skips to step

20 830. In step 830, only the sequences corresponding to information bits 1's out of the 10 sequences W1, W2, W4, W8, W16, W32, 1, M1, M2 and M4 of length 64 associated respectively with the 10 input information bits a0-a9 are all XORed to output a value of the coded symbol sequence parameter code[].

25   The (64,10) encoder operating in the method of FIG. 8 creates 64 Walsh codes of length 64, 64 inverted Walsh codes determined by inverting the 64 Walsh codes, and a total of 896 codes determined by the combination of a total of 7 mask sequences calculated by the combination of a total of 128 orthogonal codes and 3 mask functions. Therefore, the total number of codewords is 1024.

30 In addition, a (64,9) encoder creates 64 Walsh codes of length 64, Walsh codes

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calculated by adding all 1's to (or multiplying -1 by, in case of a real number) symbols of every Walsh code among the 1024 codewords, and codes determined by combining a total of 4 mask functions calculated by the combination of a total of 128 orthogonal codes and 2 mask functions among the 3 mask functions, and a

5 (64,8) encoder creates 64 Walsh codes of length 64, Walsh codes calculated by adding all 1's to (or multiplying -1 by, in case of a real number) symbols of every Walsh code among the 1024 codewords, and codes determined by combining a total of 2 mask functions calculated by the combination of a total of 128 biorthogonal codes and 1 mask function among the 3 mask functions. The (64,9)

10 encoder and the (64,8) encoder both have a minimum distance of 28. The (64,9) encoder can be realized using only two of the 3 mask functions output from the mask function generator 720 of FIG. 7A, while the (64,8) encoder can be realized using only one of the 3 mask functions output from the mask function generator 720. As stated above, the encoder can adaptively perform encoding according to

15 the number of input information bits, and can also have superior performance by increasing the minimum distance determining the performance of the encoder, as high as possible.

The (64,10) encoder uses, as codewords, 64 Walsh codes of length 64, 64

20 inverted Walsh codes calculated by inverting the 64 Walsh codes, and 896 sequences calculated by combining a total of 128 biorthogonal codes with 7 masks functions of length 64, the structure of which is illustrated in FIG. 11.

FIG. 9 illustrates an apparatus for decoding a TFCI according to an

25 embodiment of the present invention. Referring to FIG. 9, the decoder inserts '0' in the positions, punctured by the encoder, of a received signal corresponding to the TFCI symbol of length of 48, having a value of +1/-1, thereby to create a received signal r(t) of length 64. The received signal r(t) is provided to 7 multipliers 901-907 and a correlation calculator 920. The received signal r(t) is a

30 signal encoded by a predetermined Walsh code and a predetermined mask

sequence in the encoder of the transmitter. A mask generator 910 creates possible mask functions M1-M7 which can be created by 3 base masks, and provides the generated mask functions to multipliers 901-907, respectively. The multiplier 901 multiplies the received signal r(t) by the mask function M1 output from the mask

5   generator 910, and provides its output to a correlation calculator 921. The multiplier 902 multiplies the received signal r(t) by the mask function M2 output from the mask generator 910, and provides its output to a correlation calculator 922. The multiplier 907 multiplies the received signal r(t) by the mask function M7 output from the mask generator 910, and provides its output to a correlation

10   calculator 927. That is, the multipliers 901-907 multiply the received signal r(t) by their associated mask functions M1-M7 from the mask generator 910, and provide their outputs to the associated correlation calculators 921-927, respectively. By doing so, the received signal r(t) and the signals calculated by multiplying the received signal r(t) by the possible 7 mask functions, i.e., a total

15   of 8 signals are provided to the 8 correlation calculators 920-907, respectively. If the transmitter has encoded the TFCI using a predetermined mask function, any one of the outputs from the multipliers 901-907 will be a mask function-removed signal. Then, the correlation calculators 920-927 calculate 128 correlation values by correlating the received signal r(t) and the outputs of the multipliers 901-907

20   with 64 Walsh codes of length 64 and 64 inverted Walsh codes calculated by inverting the 64 Walsh codes, i.e., a total of 128 bi-Walsh (or biorthogonal) codes. The largest one of the calculated correlation values, an index of then-correlated Walsh code and an index of the correlation calculator are provided to a correlation comparator 940. The 128 Walsh codes have already been defined

25   above. The correlation calculator 920 calculates 128 correlation values by correlating the received signal r(t) with 128 bi-Walsh codes of length 64. Further, the correlation calculator 920 provides the correlation comparator 940 with the largest one of the calculated correlation values, an index of then-calculated Walsh code and an index '0' of the correlation calculator 920. Here, the index of the

30   correlation calculator is equivalent to an index of the mask function indicating

which mask function is multiplied by the received signal for the signal input to the correlation calculator. However, the mask index '0' means that no mask is multiplied by the received signal. Further, the correlation calculator 921 also calculates 128 correlation values by correlating the received signal r(t) multiplied

5 by the mask function M1 by the multiplier 901 with 128 bi-Walsh codes of length 64. Further, the correlation calculator 921 provides the correlation comparator 940 with the largest one of the calculated correlation values, an index of then-calculated Walsh code and an index '1' of the correlation calculator 921. The correlation calculator 922 calculates 128 correlation values by correlating the

10 received signal r(t) multiplied by the mask function M2 by the multiplier 902 with 128 bi-Walsh codes of length 64. Further, the correlation calculator 922 provides the correlation comparator 940 with the largest one of the 128 calculated correlation values, an index of then-calculated Walsh code and an index '2' of the correlation calculator 922. The correlation calculator 927

15 calculates 128 correlation values by correlating the received signal r(t) multiplied by the mask function M7 by the multiplier 907 with 128 bi-Walsh codes of length 64. Further, the correlation calculator 927 provides the correlation comparator 940 with the largest one of the calculated correlation values, an index of then-calculated Walsh code and an index '7' of the correlation calculator 927.

20

The correlation comparator 940 then compares the 8 largest correlation values provided from the correlation calculators 920-927, and determines the largest one of them. After determining the largest correlation value, the correlation comparator 940 outputs TFCI information bits transmitted from the

25 transmitter according to the index of the Walsh code provided from the correlation calculator associated with the determined correlation value and an index (or mask index) of the same correlation calculator. That is, the correlation comparator 940 determines a decoded signal of the received signal using the index of the Walsh code and the index of the mask function.

30

FIG. 10 illustrates a procedure for determining a Walsh code index and a mask function index for the largest correlation value by comparing the 8 correlation values in the correlation comparator 940 according to the first embodiment of the present invention, and outputting the TFCI information bits

5   accordingly. Referring to FIG. 10, in step 1000, a frequency indicating index parameter i is initialized to 1, and a maximum value, a Walsh code index and a mask index are all initialized to '0'. In step 1010, the correlation value, the Walsh code index for the correlation value and the mask index, output from the first correlation calculator 920, are stored as a first maximum value, a first Walsh

10 code index and a first mask sequence index, respectively. Thereafter, in step 1020, the first maximum value is compared with a previously stored maximum value. If the first maximum value is larger than the previously stored maximum value, the procedure goes to step 1030. Otherwise, if the first maximum value is smaller than or equal to the previously stored maximum value, the procedure

15 proceeds to step 1040. In step 1030, the first maximum value is designated as the maximum value, and the first Walsh code index and the first mask index are designated as the Walsh code index and the mask index, respectively. In step 1040, a value set for the index parameter i is compared with the number '8' of the correlation calculators, in order to determine whether comparison has been

20 completely performed on all of the 8 correlation values. If the frequency indicating index i is not equal to the number '8' of the correlation calculators in step 1040, the correlation comparator 940 increases the frequency indicating index i by 1 in step 1060 and thereafter, returns to step 1010 to repeat the above-described process using the ith maximum value, the ith Walsh code index and the

25 i^{th} mask index, output from the increased i^{th} correlation calculator. After the above process is repeatedly performed on the 8th maximum value, the 8th Walsh code index and the 8th mask index, the frequency indicating index i becomes 8. Then, the procedure goes to step 1050. In step 1050, the correlation comparator 940 outputs decoded bits (TFCI information bits) associated with the Walsh code

30 index and the mask index. The Walsh code index and the mask index

corresponding to the decoded bits are the Walsh code index and the mask index corresponding to the largest one of the 8 correlation values provided from the 8 correlation calculators.

5   In the first embodiment, the (48,10) encoder creates 48 symbols by puncturing 16 symbols after creating 64 codes. In the second embodiment below, however, unlike FIG. 7A, the encoder outputs 48 symbols after puncturing 16 symbols according to a predetermined puncturing pattern in the Walsh code generator, the 1-bit generator and the mask generator.

10

Second Embodiment

The encoding apparatus according to the second embodiment of the present invention is similar in structure to the encoder described with reference to the first embodiment. However, the only difference is that the sequences output

15 from the 1-bit generator, the Walsh code generator and the mask generator are the sequences of length 48, to which a puncturing pattern is previously applied. For example, the sequences output from the Walsh code generator, the 1-bit generator and the mask generator according to the first embodiment, from which 0th, 4th, 8th, 13th, 16th, 20th, 27th, 31st, 34th, 38th, 41st, 44th, 50th, 54th, 57th and 61st terms are

20 punctured, are used in the second embodiment.

FIG. 7B illustrates an apparatus for encoding a TFCI in an NB-TDD CDMA mobile communication system according to the second embodiment of the present invention. Referring to FIG. 7B, 10 input information bits a0-a9 are

25 provided to their associated multipliers 7400, 7410, 7420, 7430, 7440, 7450, 7460, 7470, 7480 and 7490, respectively. A base Walsh code generator 7100 simultaneously generates Walsh codes W1', W2', W4', W8', W16' and W32' of length 48, calculated by puncturing the base Walsh codes according to a predetermined puncturing rule as described above. Here, the "base Walsh codes"

30 refer to predetermined Walsh codes, by a predetermined sum of which all of

desired Walsh codes can be created. For example, for a Walsh code of length 64, the base Walsh codes include a 1st Walsh code W1, a 2nd Walsh code W2, a 4th Walsh code W4, an 8th Walsh code W8, a 16th Walsh code W16 and a 32nd Walsh code W32. A 1-bit generator 7000 continuously generates a predetermined code

5   bit. The multiplier 7400 multiplies the Walsh code W1'
(=10110110100110110101001001101100110101101100100110101001) punctured according to a predetermined puncturing rule by the Walsh code generator 7100 by the input information bit a0. The multiplier 7410 multiplies the punctured Walsh code W2' (=01101101101101101100100100100101101100100101011)

10   from the Walsh code generator 7100 by the input information bit a1. The multiplier 7420 multiplies the punctured Walsh code W4' (=000111000111000111000111000111000111000111000111) from the Walsh code generator 7100 by the input information bit a2. The multiplier 7430 multiplies the punctured Walsh code W8'

15   (=000000111111000000111111000000111111000000111111) from the Walsh code generator 7100 by the input information bit a3. The multiplier 7440 multiplies the punctured Walsh code W16' (=000000000000111111111111000000000000111111111111) from the Walsh code generator 7100 by the input information bit a4. The multiplier 7450

20   multiplies the punctured Walsh code W32' (=000000000000000000000000111111111111111111111111) from the Walsh code generator 7100 by the input information bit multiplier 7460 multiplies the symbols of all 1's output from the 1-bit generator 7000 by the input information bit a6.

25

A mask generator 7200 simultaneously outputs punctured base mask functions M1', M2' and M4' of length 48, determined by puncturing the base masks according to a predetermined puncturing pattern. The method for creating the mask functions will not be described, since it has already been described

30   above. The multiplier 7470 multiplies the punctured mask function M1'

(=01110111011·101001100001111101000101110111110000l) from the mask generator 7200 by the input information bit a7. The multiplier 7480 multiplies the punctured mask function M2' (=100111101001110101011101011101001010111001111100) from the mask

5 generator 7200 by the input information bit a8. The multiplier 7490 multiplies the punctured mask function M4' (=001000110011101100110010101111111101011001100110) from the mask generator 7200 by the input information bit a9. That is, the multipliers 7470-7490 multiply the input base mask sequences M1', M2' and M4' by the associated

10 input information bits a7-a9 in a symbol unit. An adder 7600 then adds (or XORs) the symbols output from the multipliers 7400-7490 in a symbol unit, and outputs 48 coded symbols (TFCI symbols).

FIG. 12 illustrates a control flow for encoding a TFCI in an NB-TDD

15 CDMA mobile communication system according to the second embodiment of the present invention. Referring to FIG. 12, in step 1200, a sequence of 10 input information bits a0-a9 is input and then, parameters code[] and j are initialized to '0'. Here, the coded symbol sequence parameter code[] indicates the 48 coded symbols finally output from the encoder and the parameter j is used to count the

20 48 coded symbols constituting one codeword.

Thereafter, it is determined in step 1210 whether the first information bit a0 is '1'. If the first information bit a0 is '1', the punctured base Walsh code W1' (=101101101001101101010010011011001101011011001001) is XORed with the

25 coded symbol sequence parameter code[]. Otherwise, if the first information bit a0 is not '1', the control flow skips to step 1212. Specifically, if the information bit a0 is '1', the parameter j is initialized to '0' and a jth symbol of the first punctured Walsh code W1' is XORed with a jth position code[j] of the coded symbol sequence parameter. Here, since j=0, the 0th symbol of the first Walsh

30 code is XORed with the 0th position of the coded symbol sequence parameter.

Further, it is determined whether the parameter j is 47, in order to determine whether the parameter j indicates the last coded symbol. If the parameter j is not equal to 47, the parameter j is increased by 1 and then the above process is repeated. Otherwise, if the parameter j is equal to 47, the control flow proceeds to

5   step 1212. That is, after completion of XORing on the 48 coded symbols, the control flow proceeds to the next step.

After step 1210, it is determined in step 1212 whether the second information bit a1 is '1'. If the second information bit a1 is '1', the punctured

10 base Walsh code W2'
(=011011011011011011001001001001011011001001011011) is XORed with the coded symbol sequence parameter code[] of length 48. Otherwise, if the second information bit a1 is not '1', the control flow skips to step 1214. After step 1212, it is determined in step 1214 whether the third information bit a2 is '1'. If the

15 third information bit a2 is '1', the punctured base Walsh code W4'
(000111000111000111000111000111000111000111000111) is XORed with the coded symbol sequence parameter code[] of length 48. Otherwise, if the third information bit a2 is not '1', the control flow skips to step 1216. After step 1214, it is determined in step 1216 whether the fourth information bit a3 is '1'. If the

20 fourth information bit a3 is '1', the punctured base Walsh code W8'
(=000000111111000000111111000000111111000000111111) is XORed with the coded symbol sequence parameter code[] of length 48. Otherwise, if the fourth information bit a3 is not '1', the control flow skips to step 1218. After step 1216, it is determined in step 1218 whether the fifth information bit a4 is '1'. If the fifth

25 information bit a4 is '1', the punctured base Walsh code W16'
(=000000000000111111111111000000000000111111111111) is XORed with the coded symbol sequence parameter code[] of length 48. Otherwise, if the fifth information bit a4 is not '1', the control flow skips to step 1220. After step 1218, it is determined in step 1220 whether the sixth information bit a5 is '1'. If the

30 sixth information bit a5 is '1', the punctured base Walsh code W32'

(=000000000000000000000011111111111111111111111) is XORed with the coded symbol sequence parameter code[] of length 48. Otherwise, if the sixth information bit a5 is not '1', the control flow jumps to step 1222.

5   After step 1220, it is determined in step 1222 whether the seventh information bit a6 is '1'. If the seventh information bit a6 is '1', a length-48 sequence of all 1's is XORed with the coded symbol sequence parameter code []. Otherwise, if the seventh information bit a6 is not '1', the control flow jumps to step 1224. That is, in step 1222, the symbols of the Walsh code created in the preceding steps are inverted to create a bi-Walsh code corresponding to the Walsh code, thereby to create 128 bi-Walsh codes of length 48.

        After step 1222, it is determined in step 1224 whether the eighth information bit a7 is '1'. If the eighth information bit a7 is '1', the base mask function M1' (=011101110111010011000011111010001011101111100001) punctured according to a predetermined puncturing rule is XORed with the coded symbol sequence parameter code[] of length 48. Otherwise, if the eighth information bit a7 is not '1', the control flow skips to step 1226. After step 1224, it is determined in step 1226 whether the ninth information bit a8 is '1'. If the ninth information bit a8 is '1', the punctured base mask function M2' (=100111101001110101011101011101001010111001111100) is XORed with the coded symbol sequence parameter code[] of length 48. Otherwise, if the ninth information bit a8 is not '1', the control flow skips to step 1228. After step 1226, it is determined in step 1228 whether the tenth information bit a9 is '1'. If the tenth information bit a9 is '1', the punctured base mask function M4' (= 001000110011101100110010101111111101011001100110) is XORed with the coded symbol sequence parameter code[] of length 48. Otherwise, if the tenth information bit a9 is not '1', the control flow is ended. After the process of FIG. 12, the coded symbols determined by XORing only the sequences corresponding to information bits 1's out of the 10 sequences W1', W2', W4', W8', W16',

W32', 1, M1', M2' and M4' of length 32 associated respectively with the 10 input information bits a0-a9 are stored in the parameter code[].

The (48,10) encoder creates 1024 codewords by puncturing, for example, 0th, 4th, 8th, 13th, 16th, 20th, 27th, 31st, 34th, 38th, 41st, 44th, 50th, 54th, 57th and 61st symbols from all of the codewords (Walsh codes or mask functions) of length 64 described in the first embodiment. Therefore, the total number of the codewords is 1024. In addition, a (48,9) encoder creates 64 Walsh codes of length 64 determined by puncturing 0th, 4th, 8th, 13th, 16th, 20th, 27th, 31st, 34th, 38th, 41st, 44th, 50th, 54th, 57th and 61st symbols from the 64 Walsh codes of length 64, codes calculated by adding all 1's to (or multiplying -1 by, in case of a real number) symbols of all the punctured Walsh codes among the 1024 codewords, and codes determined by combining a total of 4 mask functions calculated by the combination of a total of 128 codes and 2 mask functions among the 3 punctured mask functions, and a (48,8) encoder creates 64 Walsh codes of length 48, codes calculated by adding all 1's to (or multiplying -1 by, in case of a real number) symbols of every punctured Walsh code among the 1024 codewords, and codes determined by combining a total of 2 mask functions calculated by the combination of a total of 128 codes and 1 mask function among the 3 punctured mask functions. The (48,9) encoder and the (48,8) encoder both have a minimum distance of 18.

The (48,9) encoder can be realized using only two of the 3 mask functions output from the mask function generator of FIG. 7B, while the (48,8) encoder can be realized using only one of the 3 mask functions output from the mask function generator of FIG. 7B. In addition, a (48,7) encoder can be realized using none of the 3 mask functions output from the mask function generator of FIG. 7B. As stated above, the encoder can adaptively perform encoding according to the number of input information bits, and can also have superior performance by increasing the minimum distance determining the performance

of the encoder, as high as possible.

Next, a description of a decoder according to the second embodiment of the present invention will be made with reference to FIG. 9.

5

Referring to FIG. 9, a received signal r(t) corresponding to a TFCI symbol of length 48 having a value of +1/-1 is commonly input to 7 multipliers 901-907. The received signal r(t) is a signal encoded by a given punctured Walsh code and a given punctured mask sequence in the encoder (FIG. 7B) of the

10 transmitter. A mask generator 910 creates every possible mask function which can be created by the 3 base masks, i.e., mask functions M1'-M7' of length 48 punctured according to a given puncturing rule, and provides the generated mask functions to multipliers 901-907, respectively. The multiplier 901 multiplies the received signal r(t) of length 48 by the mask function M1' output from the mask

15 generator 910, and provides its output to a correlation calculator 921. The multiplier 902 multiplies the received signal r(t) by the mask function M2' output from the mask generator 910, and provides its output to a correlation calculator 922. The multiplier 907 multiplies the received signal r(t) by the mask function M7' output from the mask generator 910, and provides its output to a correlation

20 calculator 927. That is, the multipliers 901-907 multiply the received signal r(t) by their associated mask functions M1'-M7' from the mask generator 910, and provide their outputs to the associated correlation calculators 921-927, respectively. By doing so, the received signal r(t) and the signals calculated by multiplying the received signal r(t) by the possible 7 mask functions, i.e., a total

25 of 8 signals, are provided to the 8 correlation calculators 920-907, respectively. If the transmitter has encoded the TFCI bits using a predetermined mask function, any one of the outputs from the multipliers 901-907 will be a mask function-removed signal. Then, the correlation calculators 920-927 calculate 128 correlation values by correlating the received signal r(t) and the outputs of the

30 multipliers 901-907 with 128 bi-Walsh codes of length 48. The largest one of the

calculated correlation values, an index of then-correlated Walsh code and an index of the correlation calculator are provided to a correlation comparator 940. Here, the index of the correlation calculator is equivalent to an index of the mask function indicating which mask function is multiplied by the received signal, for

5 the signal input to the correlation calculator. However, the mask index '0' means that no mask is multiplied by the received signal. The correlation calculator 920 calculates correlation values by correlating the received signal r(t) with 128 biorthogonal codes of length 48. Further, the correlation calculator 920 provides the correlation comparator 940 with the largest one of the calculated correlation

10 values, an index of then correlated Walsh code and an index '0' of the correlation calculator 920. At the same time, the correlation calculator 921 also calculates 128 correlation values by correlating the received signal r(t) multiplied by the mask function M1' by the multiplier 901 with 128 bi-Walsh codes of length 48. Further, the correlation calculator 921 provides the correlation comparator 940

15 with the largest one of the calculated correlation values, an index of then-calculated Walsh code and an index '1' of the correlation calculator 921. The correlation calculator 922 calculates 128 correlation values by correlating the received signal r(t) multiplied by the mask function M2' by the multiplier 902 with 128 bi-Walsh codes of length 48. Further, the correlation calculator 922

20 provides the correlation comparator 940 with the largest one of the 128 calculated correlation values, an index of then-calculated Walsh code and an index '2' of the correlation calculator 922. The correlation calculator 927 calculates 128 correlation values by correlating the received signal r(t) multiplied by the mask function M7' by the multiplier 907 with 128 bi-Walsh codes of

25 length 48. Further, the correlation calculator 927 provides the correlation comparator 940 with the largest one of the calculated correlation values, an index of then-calculated Walsh code and an index '7' of the correlation calculator 927.

The correlation comparator 940 then compares the 8 largest correlation

30 values provided from the correlation calculators 920-927, and determines the

largest one of them. After determining the largest correlation value, the correlation comparator 940 outputs TFCI information bits transmitted from the transmitter according to the index of the Walsh code provided from the correlation calculator associated with the determined correlation value and an

5 index (or an index of a mask function multiplied by the received signal r(t)) of the same correlation calculator.

The correlation comparator according to the second embodiment has the same operation as that of the correlation comparator according to the first

10 embodiment. An operation of the correlation comparator according to the second embodiment will be described below with reference to FIG. 10.

Referring to FIG. 10, in step 1000, a frequency indicating index i is initialized to 1, and a maximum value, a Walsh code index and a mask index are

15 all initialized to '0'. In step 1010, the correlation value, the Walsh code index for the correlation value and the mask index, output from the first correlation calculator 920, are stored as a first maximum value, a first Walsh code index and a first mask sequence index, respectively. Thereafter, in step 1020, the first maximum value is compared with a previously stored maximum value. If the first

20 maximum value is larger than the previously stored maximum value, the procedure goes to step 1030. Otherwise, if the first maximum value is smaller than or equal to the previously stored maximum value, the procedure proceeds to step 1040. In step 1030, the first maximum value is designated as the maximum value, and the first Walsh code index and the first mask index are designated as

25 the Walsh code index and the mask index, respectively. In step 1040, a count value set for the index parameter i is compared with the number '8' of the correlation calculators, in order to determine whether comparison has been completely performed on all of the 8 correlation values. If the frequency indicating index i is not equal to the number '8' of the correlation calculators in

30 step 1040, the correlation comparator 940 increases the frequency indicating

index i by 1 in step 1060 and thereafter, returns to step 1010 to repeat the above-described process using the ith maximum value, the ith Walsh code index and the ith mask index, output from the increased i^{th} correlation calculator. After the above process is repeatedly performed on the 8th maximum value, the 8th Walsh

5   code index and the 8th mask index, the frequency indicating index i becomes 8. Then, the procedure goes to step 1050. In step 1050, the correlation comparator 940 outputs decoded bits (TFCI bits) associated with the Walsh code index and the mask index. The Walsh code index and the mask index corresponding to the decoded bits are the Walsh code index and the mask index corresponding to the

10 largest one of the 8 correlation values provided from the 8 correlation calculators.

As described above, the novel NB-TDD CDMA mobile communication system according to the present invention can efficiently encode and decode the TFCI, so as to increase error correcting capability.

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While the invention has been shown and described with reference to a certain preferred embodiment thereof, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the spirit and scope of the invention as defined by the appended

20 claims.